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Published in:
Radiocarbon

Publication date:
2011

RADIOCARBON, Vol 53, Nr 2, 2011, p 229–243

TELL SABI ABYAD, SYRIA: RADIOCARBON CHRONOLOGY, CULTURAL CHANGE, AND THE 8.2 KA EVENT

J van der Plicht[1,2] • P M M G Akkermans[2] • O Nieuwenhuyse[2] • A Kaneda[2] • A Russell[2]

ABSTRACT. At Tell Sabi Abyad, Syria, we obtained a robust chronology for the 7th to early 6th millennium BC, the Late Neolithic. The chronology was obtained using a large set of radiocarbon dates, analyzed by Bayesian statistics. Cultural changes observed at ~6200 BC are coeval with the 8.2 ka climate event. The inhabitation remained continuous.

INTRODUCTION

Climatic variations are observed in various proxy records during the Early Holocene, the most pronounced one the so-called "8.2 ka event," 8200 yr ago (Alley et al. 1997). This abrupt climate change event, caused by drainage of a huge glacial meltwater lake in North America, was first (and still is) most notably observed in the Greenland ice, and is characterized by a ~160-yr-long cooling period of ~3 °C (Kobashi et al. 2007). This event has been observed in marine, lacustrine, and terrestrial records, mainly on the Northern Hemisphere (Rohling and Pälike 2005; Wiersma 2008).

Both climatologists and policy makers today have come to appreciate that archaeological insights in human responses to climate change in the past are highly relevant for our own modern society facing future climate change. The 8.2 ka event has been used as an example in popular blockbuster movies (in particular, *The Day After Tomorrow*) and in a recent White House policy report (Schwartz and Randall 2003). In spite of this emphasis, however, we remain virtually in the dark with regard to understanding how prehistoric communities coped with this event. Archaeologists have recently suggested dramatic socioeconomic downfalls, massive population migrations, increases in violence and warfare, and general mayhem in Europe and the Near East as a result of the event (Weiss and Bradley 2001; Weiss 2003; Weninger et al. 2006), but sound data for confirming such dramatic scenarios are mostly absent. The full understanding of the 8.2 ka event, including its temporal aspects, needs to be improved (Morrill and Jacobsen 2005; Jansen et al. 2007).

Evidently, apart from the human response, it is crucial to ascertain firm chronologies. At a recent workshop dedicated to the 8.2 ka event, one of the main conclusions was that "... significant problems remain. The most important and one that was repeatedly raised was that of chronology. The offset (around 200 years) in the terrestrial dates for the drainage and the ice core chronologies, while within error bars, is still quite significant" (Schmitt and Jansen 2006).

Chronologies are an essential first step for synchronizing climate and culture change. Of course, while fully recognizing that synchronicity does not by itself imply causality, it is also clear that discussions of human responses to past climate change are often hampered by poor chronological control. With insufficient control over archaeological sequences, it becomes dangerously easy to "match" cultural sequences to make them fit reconstructed patterns of climate change. Both so-called climate determinists and cultural determinists must be able to rely on sound chronological frameworks, both for climate and for cultural change.

Here, we present a significant contribution to both the chronology of the climate event as well as to its human response, obtained from what is possibly the best data set for investigating the repercussions of the 8.2 ka event in the Near East: the Late Neolithic site Tell Sabi Abyad in northern Syria.

[1]Center for Isotope Research, Groningen University, Groningen, the Netherlands. Corresponding author.
Email: j.van.der.plicht@rug.nl.
[2]Faculty of Archaeology, Leiden University, Leiden, the Netherlands.

Extensive excavations during the past 25 yr revealed a unique, continuous sequence of 7th and early 6th millennium occupation layers, unparalleled at any other site in the Near East so far (Akkermans and Schwartz 2003). The layers of settlement have been extensively dated by radiocarbon, which showed that habitation at the site encompassed the 8.2 ka event. Altogether, 145 ^{14}C dates were analyzed by Bayesian statistics, establishing the best-dated chronology for a Late Neolithic site in the Near East thus far. Here, we present the dates and their analysis, and discuss the consequences of our research in terms of the 8.2 ka event.

THE EXCAVATIONS AT TELL SABI ABYAD

Tell Sabi Abyad is a Neolithic archaeological site in northern Syria (see Figure 1). It is located in the Balikh Valley, about 30 km from the Syro-Turkish border. The region is rather marginal for dry farming (200–300 mm annual precipitation). Even small changes in the amount of precipitation in this region can have drastic results, in the past as well as today—as seen in the present-day drought period that has hit Syria (Akkad 2009). Indeed, climate models predict for the region considered here a shift to drier and colder conditions during the 8.2 ka event (Wiersma and Renssen 2006). This makes the site a prime test case for investigating the human response.

Figure 1 The location of Tell Sabi Abyad in northern Syria

The mound of Tell Sabi Abyad has been shown to have a highly complex history of settlement. This article is primarily concerned with the extensive excavations in the northwestern area of the site, termed Operation III. The work in Operation III revealed 4 successive phases of deposition, which we have named Sequence A (~7100–6200 BC), Sequence B (~6200–5900 BC), Sequence C (~5900–5800 BC), and Sequence D (~5700–5500 BC). A schematical drawing of the site indicating the various stratigraphic phases is shown in Figure 2.

The excavations in Operation III show that the earliest stratigraphic phase (sequence A) is comprised of at least 12 distinct levels starting during the Initial Pottery Neolithic (7000–6700 BC) and continuing through the Early Pottery Neolithic into the early stages of the Pre-Halaf Pottery stage

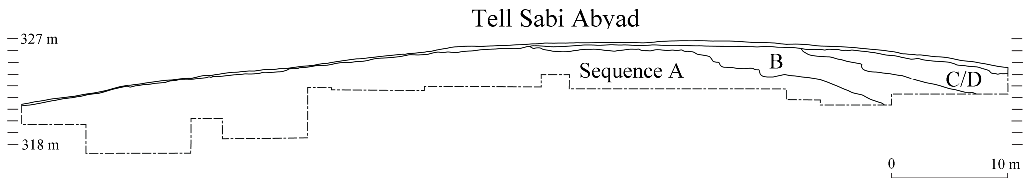

Figure 2 Schematic illustration of the so-called Operation III excavations at Tell Sabi Abyad. Sequences A and B are discussed in this paper; sequences C/D are not.

(until ~6200 BC; see Nieuwenhuyse et al. 2010 for the terminology). Sequence B continues with a sequence of at least 8 levels after ~6200 BC (Pre-Halaf and Transitional periods). This is followed by deposits dated to the Early Halaf (Sequence C) and the Middle Halaf (Sequence D) periods.

For the present paper, only sequences A and B are relevant. There are noticeable differences between sequences A and B, suggesting that the transition between these 2 periods was realized within a short timespan around 6200 BC (Akkermans et al. 2006).

ABRUPT CULTURAL CHANGE IN THE LATE NEOLITHIC ABOUT 6200 BC

Around 6200 BC, the inhabitants shifted the location of their village from the high western part of Tell Sabi Abyad, where continuous occupation over almost a millennium had accumulated a steep tell, towards the eastern slopes of this ancient mound. That is, the village moved from west (Sequence A) to east (Sequence B). This was not a very drastic move, as the site as a whole was never deserted, but the shift was associated with the spread of new architectural forms. Large storage buildings consisting of many tiny cubicles made their appearance. Circular buildings (*tholoi*), which were found incidentally in the earlier 7th millennium, now suddenly occurred in large numbers. The community transformed from autonomous households with a subsistence based on agriculture and domesticated ovicaprids and pig, towards a much more diversified population that included both mobile pasturalists and sedentary agriculturalists.

Zoological studies and residue analyses point to key changes in animal husbandry, notably the use of sheep and goats for milk and fiber production (Evershed et al. 2008; Russell 2010). A "fiber revolution" is suggested by a substantial increase in the number of spindle whorls after 6200 BC; their size and weight suggest they were used for wool production. Finally, animal exploitation patterns show a substantial (albeit temporary) reduction of pig husbandry in favor of cattle. This change can possibly be linked to an aridification of the environment caused by the 8.2 ka event, as pigs are particularly maladapted to arid conditions (Balter 2010; Russell 2010).

Accompanying changes include the introduction of stamp seals and abstract tokens to control access to goods or services, pointing to changing concepts of personal property. The material culture furthermore shows the development of advanced ceramic storage containers and the introduction of new types of cooking ware. There were significant changes in the social-symbolic roles of ceramics as well, as indicated by the sudden introduction and subsequent rapid increase of ceramics decorated with abstract, geometric motifs. Decorated pottery styles were becoming similar over vast geographic distances, pointing to significantly increased social networking. The lithic industry saw a technical disinvestment in stone tool manufacture; the consumption of stone axes and of stone vessels was reduced significantly (Akkermans et al. 2006, 2009, 2010; Nieuwenhuyse et al. 2010).

All these cultural changes took place or began to manifest themselves around 6200 BC; they started during level A1 and were mostly fully implemented during level B8, i.e. within a short timeframe.

It is striking that these cultural changes all took place around the time of the 8.2 ka climate event. To investigate the possible contemporaneity of the "cultural event" with the "climate event," a good chronology for the occupation sequences at Tell Sabi Abyad is necessary. This was established by an extensive ^{14}C dating program.

DATING THE LATE NEOLITHIC SEQUENCE AT TELL SABI ABYAD

For the 7th to early 6th millennium BC layers of Tell Sabi Abyad, more than 300 ^{14}C dates have been obtained thus far. All ^{14}C dates were measured at the Groningen radiocarbon facility. For the so-called Operation III series of excavations, the many building levels corresponding to sequences A and B (see Figure 2) were sampled for ^{14}C dating. Most samples discussed here were obtained during 2005–2009. From our extensive set of dated samples, 246 were selected as our "first choice" data set. Of these, 239 are accelerator mass spectrometry (AMS) dates (laboratory code GrA); 7 were conventional (laboratory code GrN). The routing through the AMS or conventional laboratory was determined by sample size only. There are 83 dates for fossil bones (both human and faunal), and 163 dates for charcoal, (charred) seeds/grains, and a single small sample of wood.

In this paper, we do not discuss the bone dates; we only use the dates provided by the charred botanical samples. The extensive sample of charcoal/seed dates is preferred because they provide more certainty for stratigraphic (Bayesian) analysis. Practically all samples designated as charcoal in the date list represent in fact unidentified seeds/grains, shrubs, and twigs, i.e. short-lived sample material. Possible "old wood effects" are not an issue here (see also Bruins et al. 2011). The samples come from a closed context: collected from bin fills, ovens, hearths, and rooms. Thus, they represent primary fills: the contents of the fireplace, perfectly dating the last usage of the fireplace and its association. The samples therefore fulfill the stringent requirements for Bayesian analysis (e.g. Bayliss 2009). Samples taken from pits and open areas are less reliable and therefore not used, since they may date to different periods.

The analysis of the bone samples is more problematic, which is the reason they are not (yet) used for the Bayesian analysis, which requires prime quality sample material (Bayliss 2009; Bronk Ramsey 2009). A large sample of faunal bones has been analyzed for the stable isotopes ^{13}C and ^{15}N (Russell 2010). In terms of standard ^{14}C sample quality parameters like collagen content, C%, N%, and C/N ratios (e.g. van Strydonck et al. 1999), the success rate was only around 30%. The success rate for the bones from the human burials that were dated by ^{14}C is comparable. A large (>100 bones) sample of burials is still waiting processing in Groningen. When these are analyzed, we will have a better understanding of the quality and degradation process, enabling us to select bone dates possibly acceptable to be included in the Bayesian analysis.

The list of 163 dates with their context is given in the Appendix. The dates are reported in BP, and the calibrated date ranges in BC (1-σ confidence level). All numbers are rounded to the nearest 5. Of these dates, 18 were identified as outliers, leaving 145 samples for the ultimate Bayesian analysis: 109 for sequence A and 36 for sequence B.

With only very few exceptions, all samples underwent the standard AAA pretreatment. All accepted dates satisfy the usual sample quality criteria: the carbon content of charcoal should be 68 ± 5%, and the $\delta^{13}C$ value should be around –22‰ (Mook and Streurman 1983; van Strydonck et al. 1999). There is one $\delta^{13}C$ value that shows C_4 plant material ($\delta^{13}C = -14.69$‰); interestingly, this sample had to be rejected because it is a large outlier in age.

In the timeframe of interest here, calibration of individual ^{14}C dates yield complex and broad probability distributions. The temporal resolution on the calendar timescale is then not good enough to derive precise chronological inference. The temporal resolution can significantly be improved by additional information to the ^{14}C dates, by applying Bayesian statistics. This enables calibrated ^{14}C ages to be included along with their relative archaeological stratigraphy (Bronk Ramsey 2001, 2009; Bayliss 2009). Only selected dates with good quality can be used, from both the ^{14}C laboratory point of view, as well as archaeology: most importantly, a clear context (e.g. van der Plicht et al. 2009). In the case of Tell Sabi Abyad, this is the selection of 145 samples mentioned above.

The Bayesian analysis of both sequences (A and B) was performed using the OxCal v 4.1 program (Bronk Ramsey 2009) and the IntCal09 calibration curve data (Reimer et al. 2009). The dates were grouped per level separated by boundaries. The numbers are summarized in Table 1 (Sequence A) and Table 2 (Sequence B). The tables show the levels, the number of ^{14}C dates per level, and the calibrated date ranges (1-σ level) in BC calculated by OxCal.

Table 1 Results of Bayesian analysis: date ranges for sequence A.

Level	nr of ^{14}C dates	Date range (BC)
A1	23	6330–6225
A2	16	6385–6325
A3	6	6395–6375
A4	15	6455–6385
A5	8	6485–6450
A6	2	6505–6480
A7	14	6570–6490
A8	7	6625–6575
A9	4	6675–6620
A10	6	6760–6680
A11	4	6825–6760
A12	4	6865–6775

Table 2 Results of Bayesian analysis: date ranges for sequence B.

Level	nr of ^{14}C dates	Date range (BC)
B3	2	6040–5995
B4	4	6050–6015
B5	6	6075–6040
B6	5	6095–6065
B7	6	6125–6080
B8	13	6180–6105

The results show a consistent and continuous chronology of the Late Neolithic levels. In 2 cases (levels A1 and B8), a subdivision of 4 and 3 levels, respectively, can be made, based on the sequence of ovens and hearths. This is not further discussed here.

The calculated age ranges (Tables 1, 2) are shown graphically in Figure 3. The figure shows the complete chronology of the Late Neolithic sequence in Operation III during the 7th and early 6th millennia. The inhabitation is continuous; the chronology of sequence A is followed by sequence B. At first sight, Figure 3 seems to indicate a short break between occupation levels A1 and B8. However, the hiatus does not exist in reality, as there is a level B9—albeit without ^{14}C dates so far. Stratigraphically, this level B9 bridges the gap between the levels A1 and B8.

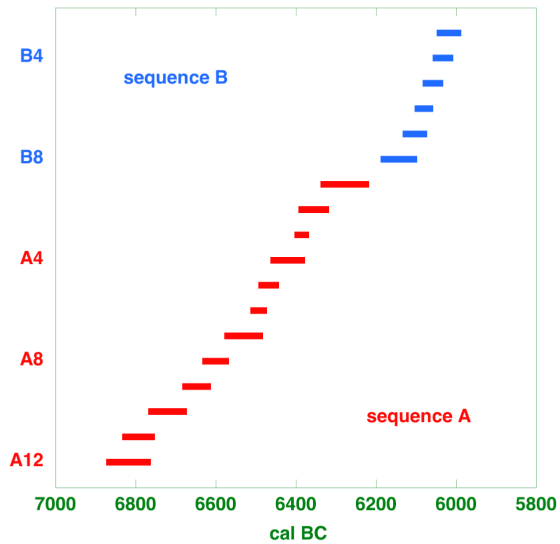

Figure 3 High temporal resolution ^{14}C chronology of the archaeological levels of Tell Sabi Abyad.

The OxCal program calculates the boundaries "end sequence A" and "beginning sequence B" as well. Statistically, these boundaries overlap at the 1-σ confidence level.

THE CHRONOLOGY OF THE 8.2 KA EVENT AS DERIVED FROM CLIMATE PROXIES

Unfortunately, no pollen records or other such direct climate proxies are available at Tell Sabi Abyad. However, the 8.2 ka climate event has been observed in many records elsewhere during the last decade (for a recent review, see Wiersma 2008 and references therein). Here, we discuss only those records most relevant for the chronological aspects of the 8.2 ka event. We concentrate on those proxies that are dated directly, by dendrochronology, ice counting, and, in particular, by ^{14}C. They are summarized in Figure 4, plotted for the time range 8800–7800 cal BP. The event started with the drainage of Lake Agassiz. This was a "superlake" on the North American continent, caused by melting of the retreating Laurentide Ice Sheet (Clarke et al. 2003).

In marine records, the 8.2 ka climate event is ^{14}C dated with relative large uncertainty to 8160–8740 cal BP (Barber et al. 1999). The event is coeval (8380–8290 cal BP) with a significant reduction of the North Atlantic Deep Water (NADW) formation, as observed in the Labrador Sea (Kleiven et al. 2008). Also, the cold meltwater appeared to come in 2 pulses, the first ~8500 yr ago, the second 200 yr later: 8280–8380 and 8470–8580 cal BP, respectively. This was inferred from reading the history of both surface and bottom waters in a single marine core (Ellison et al. 2006). We note that (for the ^{14}C aspects) these marine records suffer from uncertainties in reservoir corrections (in particular during times of climatic upheavals).

The event is (given the published chronologies) followed by a sharp cooling event on Greenland, as observed in ice cores (Kobashi et al. 2007; Thomas et al. 2007 and references). Taken together, the time range for the event (analyzed for a composite of ice-core records Dye3/GRIP/GISP2 and NGRIP) is 8247–8025 cal BP. The ice-core records represent a high temporal resolution; the counting error (absolute timescale error) of the ice layers is stated as ~50 yr.

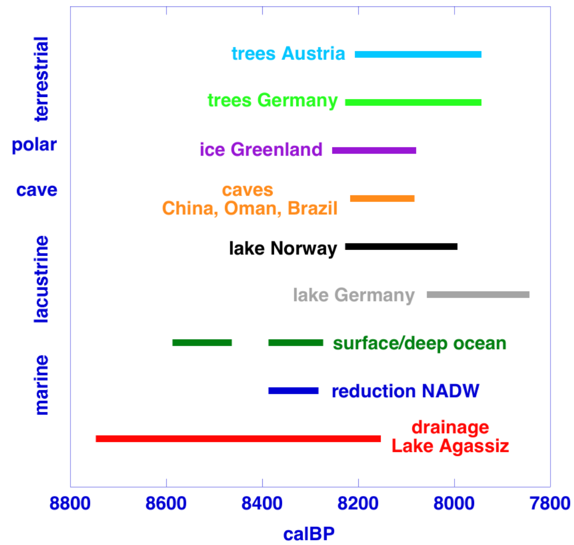

Figure 4 Chronological comparison of the 8.2 ka event as observed in selected proxy records from marine, lacustrine, polar, and terrestrial environments. For references, see the text.

Lacustrine climate proxy records were the first terrestrial records yielding chronological information for the 8.2 ka event. Variations in stable oxygen isotope ratios of ostracod valves from Lake Ammersee (southern Germany) for the first time confirmed the 8.2 ka climate event in Europe (von Grafenstein et al. 1998). The core is ^{14}C dated but the absolute age model is not robust. From this article, we infer a time range of 8050–7850 cal BP for the event. More recently, the 8.2 ka event is well dated in a lake from Norway, by applying ^{14}C wiggle-matching of terrestrial macrofossils (Hormes et al. 2009). The resulting age range for the 8.2 ka event is 8000–8220 cal BP.

A combination of speleothem records from Brazil, China, and Oman clearly show the 8.2 ka event. The chronology is obtained from U-series-dated ^{18}O paleoclimate records. The 8.2 ka event is dated to 8090–8210 cal BP (Chen et al. 2009).

In pure terrestrial records, the 8.2 ka climate deterioration is observed in tree-ring replication records in central Europe. In terms of chronologies, these can be considered the best proxies, because dendrochronology provides an absolute timescale. In German tree rings (subfossil oaks from the Main River), the 8.2 ka event is observed at 8220–7950 cal BP (Spurk et al. 2002). In trees from the Austrian Alps, the event is observed at 8200–7950 cal BP (Nicolussi et al. 2009). Both central European tree-ring chronologies for the 8.2 ka event are consistent with each other, as well as with the Greenland ice cores.

The age ranges for the 8.2 ka event mentioned above are shown in Figure 4. The data, selected from the literature, are representative for dating the 8.2 ka event in marine, lacustrine, polar, and terrestrial records.

DISCUSSION: SYNCHRONIZING CLIMATIC AND CULTURAL EVENTS

The chronology for Tell Sabi Abyad, as obtained from the ^{14}C analysis, is shown in Figure 5, which is essentially the same as Figure 3, but now includes a comparison with the chronology obtained for the 8.2 ka event. For the latter, we show only the 8.2 ka event as observed in ice cores, using the chronology of Thomas et al. (2007) for the combined Greenland ice cores, which is also consistent with the tree rings.

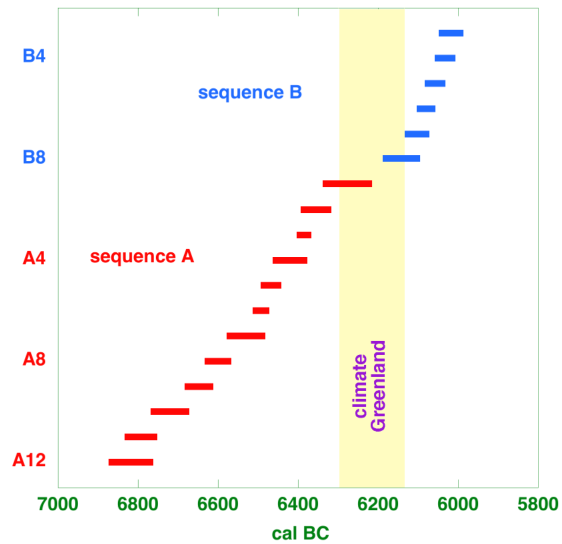

Figure 5 High temporal resolution ^{14}C chronology of the archaeological levels of Tell Sabi Abyad (same as in Figure 3), compared with the duration of the 8.2 ka climate event as observed in Greenland ice cores.

This comparison shows that the stratigraphic transition from Sequence A to B, which represents the onset of large-scale societal change during the otherwise continuous inhabitation at Tell Sabi Abyad, is clearly contemporaneous with the 8.2 ka climate event. The societal changes at Tell Sabi Abyad started at the timeframe corresponding to level A1, and are fully implemented at level B8. The data can be interpreted as a long-lasting period of gradual change, accelerated during the transition from Sequence A to B.

It is striking that a similar observation is made by Rohling and Pälike (2005) in their review article on the 8.2 ka event. They note that the climate anomalies span 400–600 yr, starting ~8600 yr ago, and that more sudden climate changes ~8200 yr ago appear superimposed on this long-term cooling. Are these climate anomalies possibly reflected in the history of Tell Sabi Abyad?

Earlier, we reported (Akkermans et al. 2010) on our research, using a sequence from earlier excavations (called Operation I). Situated just a few hundreds of meters southeast of Operation III, the excavated sequence from Operation I is completely parallel to the sequence B reported here, and had been dated by ^{14}C as well, albeit much less intensively. The archaeological observations of these levels are the same as for sequence B. The conclusion remains the same: this sequence also shows continuous occupation of Tell Sabi Abyad throughout the duration of the 8.2 ka event.

CONCLUSION

At Tell Sabi Abyad, Syria, we obtained a robust chronology for the 7th to early 6th millennium BC, the Late Neolithic. The chronology was obtained using a large (145 samples) set of ^{14}C dates, analyzed by Bayesian statistics. This now represents the best-dated continuous chronology of this time range in the Near East.

At this settlement, significant cultural change appears to have taken place around 6200 BC. The ^{14}C chronology now shows that this "cultural event" is contemporaneous with a well-known "climate event": the so-called 8.2 ka event, a cold period observed in Greenland ice and other paleoclimate records. Summarizing, the climate event and societal change synchronize well.

Synchronicity does not imply causality, however. We need to be aware of the danger of determinism. Human societies do not simply roll and flow with the climate tide (deMenocal 2001; Rosen 2007); societies develop coping mechanisms and are often remarkably resilient. But we cannot ignore the compelling evidence for substantial cultural change and diversification during the time of climate change around 6200 BC. Fundamental transitions such as those observed at Tell Sabi Abyad must have required a strong impetus as they penetrated all realms of life at the Neolithic settlement and manifested themselves in decades. We believe that the 8.2 ka climate event was among the forcing factors behind these changes.

However one reconstructs causality with regard to the effects of climate change, what is clear in any case is that our observations refute the deterministic "collapse of cultures" stance with which the archaeological record is currently replete. Prehistoric societies in the Near East were apparently able to adapt to variations in weather and climate. To the Late Neolithic inhabitants of Tell Sabi Abyad, drought represented a challenge that required the implementation of developed coping strategies.

ACKNOWLEDGMENTS

The project is funded by the Netherlands Organisation for Scientific Research (NWO), dossier 360-62-040. Groningen BSc student Jan Boelens is thanked for his work on the Bayesian analysis.

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APPENDIX

Date list of ^{14}C samples of charcoal and other charred materials for Tell Sabi Abyad. It shows the laboratory code (GrA: Groningen AMS, GrN: Groningen conventional), dated material, prehistoric level, sample context, ^{14}C age and error (1 σ), calibrated age range (1 σ), sample organic content (C_v in %), stable carbon isotope ratio ($\delta^{13}C$ in ‰), and archaeological identification number.

Appendix Date list of ^{14}C samples of charcoal and other charred materials for Tell Sabi Abyad.

Lab code	Material	Level	Context	^{14}C BP	1 σ	$\delta^{13}C$ ‰	C_v %	cal BC (1 σ)	Sample ID
GrA-33001	Charcoal	A12	pit fill GO	7955	35	–23.99	62	7030–6770 (68.2%)	SN05-333
GrA-33002	Charcoal	A12	wall fills FV, FT, FW, FF, GJ, GH, GF	8005	35	–23.95	63	7050–6830 (68.2%)	SN05-334
GrA-33007	Charcoal	A12	hearth fill FX	8040	35	–22.65	60	7070–6840 (68.2%)	SN05-348
GrA-42821	Charcoal	A12	hearth fill FX	8010	45	–23.42	61	7055–6830 (68.2%)	SN05-158
GrA-33006	Charcoal	A11	hearth fill FU	7930	35	–22.56	61	7005–6690 (68.2%)	SN05-343
GrA-33009	Charcoal	A11	hearth fill FU	7990	35	–19.46	53	7045–6830 (68.2%)	SN05-332
GrA-42817	Charcoal	A11	hearth fill FK	7890	50	–24.06	58	6900–6890 (1.0%) 6825–6645 (67.2%)	SN05-146
GrA-42818	Charcoal	A11	hearth fill FJ	7995	45	–24.10	58	7050–6825 (68.2%)	SN05-160
GrA-42820	Charcoal	A11	ash pocket	8615	50	–25.23	51	7680–7580 (68.2%)	SN08-480
GrA-42810	Charcoal	A10	hearth fill FD	7970	45	–18.22	57	7035–6820 (68.2%)	SN05-090
GrA-42811	Charcoal	A10	hearth fill FA	7925	45	–25.22	41	7020–6690 (68.2%)	SN05-091
GrA-42812	Charcoal	A10	hearth fill EZ	7985	45	–22.17	53	7045–6905 (46.8%) 6890–6825 (21.4%)	SN05-096
GrA-42813	Charcoal	A10	hearth fill FB	7910	45	–24.11	57	6985–6655 (68.2%)	SN05-122
GrA-42815	Charcoal	A10	hearth fill FO	7940	45	–24.62	58	7025–6695 (68.2%)	SN05-214
GrA-32059	Charcoal	A10	open area	7930	45	–25.16	60	7025–6690 (68.2%)	SN04-196
GrA-42801	Charcoal	A9	hearth fill ED	7705	45	–23.16	58	6595–6480 (68.2%)	SN05-009
GrA-42802	Charcoal	A9	hearth fill EH	8270	45	–25.95	54	7450–7185 (68.2%)	SN05-021
GrA-42804	Charcoal	A9	hearth fill EM	7795	45	–24.34	60	6680–6590 (68.2%)	SN05-034
GrA-42806	Charcoal	A9	hearth fill ET	7820	45	–23.40	60	6690–6595 (68.2%)	SN05-067
GrA-42807	Charcoal	A9	hearth fill CC	7740	45	–25.20	57	6610–6505 (68.2%)	SN08-109
GrA-42785	Charcoal	A8	oven fill CB	7725	45	–22.02	59	6600–6495 (68.2%)	SN08-105
GrA-42786	Charcoal	A8	oven fill BK	7715	45	–23.52	63	6595–6495 (68.2%)	SN08-107
GrA-42787	Charred seeds	A8	oven fill BJ	7835	45	–23.67	36	6735–6725 (2.9%) 6700–6595 (65.3%)	SN08-128
GrA-42792	Charcoal	A8	hearth fill DP	7760	45	–22.80	61	6645–6565 (57.9%) 6550–6525 (10.3%)	SN05-279
GrA-42797	Charcoal	A8	hearth fill EC	7775	45	–23.01	60	6650–6565 (61.1%) 6545–6530 (7.1%)	SN05-008
GrA-42800	Charcoal	A8	hearth fill DZ	7780	45	–24.21	57	6655–6565 (62.5%) 6545–6530 (5.7%)	SN05-234
GrA-42850	Charcoal	A8	hearth fill EJ	7715	45	–25.68	48	6595–6495 (68.2%)	SN05-285
GrA-31875	Charcoal	A7	hearth fill DD	7690	45	–19.86	67	6590–6470 (68.2%)	SN04-130
GrA-31876	Charcoal	A7	hearth fill DB	7700	50	–23.01	68	6590–6480 (68.2%)	SN04-136
GrA-31877	Charcoal	A7	hearth fill DL	7695	45	–24.38	52	6590–6475 (68.2%)	SN04-180
GrA-32047	Charcoal	A7	pit fill DS	7640	45	–22.60	57	6560–6550 (4.3%) 6510–6435 (63.9%)	SN04-114
GrA-32048	Charcoal	A7	pit fill DT	7705	45	–24.82	59	6595–6480 (68.2%)	SN04-116
GrA-32049	Charcoal	A7	pit fill DU	7735	45	–24.11	60	6610–6500 (68.2%)	SN04-118
GrA-42781	Charcoal	A7	hearth fill N	7680	45	–25.08	60	6570–6540 (17.7%) 6535–6465 (50.5%)	SN04-078
GrA-42788	Charcoal	A7	hearth fill CZ	7710	40	–23.54	66	6595–6500 (68.2%)	SN05-185
GrA-42790	Charcoal	A7	hearth fill DE	7710	45	–22.92	61	6595–6495 (68.2%)	SN05-219
GrA-42791	Charcoal	A7	hearth fill CV	7665	45	–23.16	60	6570–6545 (13.1%) 6530–6455 (55.1%)	SN05-231

Appendix Date list of ^{14}C samples of charcoal and other charred materials for Tell Sabi Abyad. *(Continued)*

Lab code	Material	Level	Context	^{14}C BP	1 σ	$\delta^{13}C$ ‰	C_v %	cal BC (1 σ)	Sample ID
GrA-42795	Charcoal	A7	hearth fill ER	7725	45	–25.29	60	6600–6495 (68.2%)	SN05-324
GrA-42796	Charcoal	A7	hearth fill DH	7635	45	–24.79	46	6560–6550 (2.3%) 6510–6435 (65.9%)	SN04-143
GrA-42798	Charcoal	A7	hearth fill DY	7700	45	–24.73	60	6590–6480 (68.2%)	SN05-225
GrN-29713	Charcoal	A7	hearth fill DF	7765	30	–23.89	67	6645–6570 (64.9%) 6540–6530 (3.3%)	SN04-156
GrA-32052	Charcoal	A6	open area under floor CO	8170	80	–22.59	60	7305–7215 (23.5%) 7200–7065 (44.7%)	SN04-171
GrA-42782	Charcoal	A6	hearth fill CP	7535	45	–23.49	59	6450–6380 (68.2%)	SN05-129
GrN-29706	Charcoal	A6	hearth fill J	7570	60	–25.14	64	6480–6380 (68.2%)	SN04-076
GrA-32051	Charcoal	A5	hearth fill AZ	7625	45	–22.54	57	6505–6430 (68.2%)	SN04-153
GrA-32053	Charcoal	A5	hearth fill BB	7545	45	–24.54	58	6455–6390 (68.2%)	SN04-181
GrA-32056	Charcoal	A5	pit fill CL	7760	50	–19.33	52	6645–6510 (68.2%)	SN04-028
GrA-32062	Charcoal	A5	bin fill BO	7740	45	–19.13	60	6610–6505 (68.2%)	SN04-230
GrA-42775	Charcoal	A5	bin fill #217	7725	45	–20.86	50	6600–6495 (68.2%)	SN04-102
GrA-42776	Charcoal	A5	bin fill AU	7595	45	–22.47	56	6480–6420 (68.2%)	SN04-106
GrA-42780	Charcoal	A5	hearth fill GP	7655	45	–23.29	64	6570–6545 (10.7%) 6530–6450 (57.5%)	SN08-496
GrA-42889	Charcoal	A5	hearth fill HD	7555	45	—	—	6460–6395 (68.2%)	SN08-359b
GrA-24219	Charcoal	A4	room fill	7570	50	—	—	6465–6400 (68.2%)	SN02-117
GrA-24248	Charcoal	A4	oven fill AJ, on floor AN	7720	50	–25.19	58	6600–6495 (68.2%)	SN02-115
GrA-26877	Charcoal	A4	hearth fill AC	27,790	370	—	—	30,490–29,545 (68.2%)	SN03-127
GrA-26927	Charcoal	A4	room fill	7475	45	—	—	6415–6345 (40.0%) 6315–6260 (28.2%)	SN03-107
GrA-26928	Charcoal	A4	room fill	7525	45	—	—	6450–6370 (68.2%)	SN03-124
GrA-32058	Charred grains	A4	pit fill CS	7495	45	–23.28	58	6430–6355 (54.3%) 6295–6265 (13.9%)	SN04-012
GrA-32063	Charcoal	A4	bin fill EU	12,230	60	–25.94	66	12,240–12,020 (68.2%)	SN04-233
GrA-42728	Charcoal	A4	room fill	7540	40	–24.33	62	6450–6390 (68.2%)	SN04-212
GrA-42729	Charcoal	A4	bin fill DP	7540	40	–25.79	58	6450–6390 (68.2%)	SN08-017
GrA-42730	Charcoal	A4	hearth fill DT	7460	40	–25.51	65	6395–6340 (33.3%) 6315–6255 (34.9%)	SN08-066
GrA-42732	Charcoal	A4	hearth fill FT	7475	40	–25.02	62	6415–6350 (40.3%) 6315–6260 (27.9%)	SN08-164
GrA-42733	Charcoal	A4	hearth fill FL	7445	40	–25.60	63	6380–6330 (28.4%) 6320–6255 (39.8%)	SN08-169
GrA-42764	Charcoal	A4	hearth fill ED	7505	40	–24.49	63	6435–6360 (60.9%) 6290–6270 (7.3%)	SN08-383
GrA-42766	Charcoal	A4	bin fill GE	18,850	80	–27.40	60	20,590–20,225 (68.2%)	SN08-314
GrA-42768	Charcoal	A4	hearth fill HT	7465	40	–23.62	58	6400–6340 (34.7%) 6315–6260 (33.5%)	SN08-501
GrA-42778	Charcoal	A4	hearth fill DJ	7475	40	–23.21	63	6415–6350 (40.3%) 6315–6260 (27.9%)	SN08-372
GrA-42901	Charcoal	A4	hearth fill DA/DC/DE	7425	50	—	—	6370–6280 (50.2%) 6275–6240 (18.0%)	SN08-499b
GrN-29714	Charcoal	A4	oven fill ES	7680	30	–23.70	69	6570–6545 (15.5%) 6530–6465 (52.7%)	SN04-158
GrA-42481	Charred seeds	A3	room fill	7500	45	—	—	6435–6355 (56.6%) 6295–6265 (11.6%)	SN07-613
GrA-42723	Charcoal	A3	room fill	7450	40	–25.60	63	6385–6335 (29.5%) 6320–6255 (38.7%)	SN07-597

Appendix Date list of ^{14}C samples of charcoal and other charred materials for Tell Sabi Abyad. *(Continued)*

Lab code	Material	Level	Context	^{14}C BP	1 σ	δ^{13}C ‰	C_v %	cal BC (1 σ)	Sample ID
GrA-42724	Charred seeds	A3	room fill, filled with burnt soil	7435	40	–22.55	62	6370–6250 (68.2%)	SN08-323
GrA-42727	Charcoal	A3	room fill	7455	40	–23.35	67	6395–6335 (31.9%) 6315–6225 (36.3%)	SN07-601
GrN-29719	Seeds	A3	room fill AI with burned grain	7485	15	–23.44	69	6415–6365 (68.2%)	SN04-221
GrN-29720	Seeds	A3	room fill AI with burned grain	7450	15	–23.47	68	6380–6350 (23.8%) 6315–6260 (44.4%)	SN04-222
GrA-32046	Charred seeds	A2	open area	7440	45	–24.79	60	6380–6325 (28.1%) 6320–6250 (40.1%)	SN04-067
GrA-42463	Charcoal	A2	oven fill BN	7535	45	–23.82	61	6450–6380 (68.2%)	SN08-016
GrA-42465	Charcoal	A2	hearth fill BQ	7510	45	–25.50	65	6440–6360 (61.0%) 6290–6270 (7.2%)	SN08-068
GrA-42466	Charcoal	A2	hearth fill BR	7675	45	–24.78	57	6570–6540 (15.9%) 6535–6465 (52.3%)	SN08-104
GrA-42480	Charcoal	A2	oven fill FL inside *tholos*	7425	45	–22.74	59	6365–6280 (50.5%) 6275–6240 (17.7%)	SN07-598
GrA-42489	Charcoal	A2	oven fill FL	7475	45	–15.59	55	6415–6345 (40.0%) 6315–6260 (28.2%)	SN08-008
GrA-42490	Charcoal	A2	bin fill BS	7395	45	–24.38	66	6360–6285 (40.3%) 6270–6225 (27.9%)	SN08-131
GrA-42491	Charcoal	A2	hearth fill EW	7400	45	–22.21	62	6365–6285 (42.1%) 6275–6225 (26.1%)	SN08-153
GrA-42492	Charcoal	A2	hearth fill CD	7380	45	–24.13	66	6365–6285 (34.9%) 6275–6215 (33.3%)	SN08-188
GrA-42494	Charcoal	A2	room fill	7425	45	–26.73	65	6365–6280 (50.5%) 6275–6240 (17.7%)	SN08-378
GrA-42495	Charcoal	A2	hearth fill DU	7465	45	–26.35	60	6400–6340 (35.0%) 6315–6255 (33.2%)	SN08-477
GrA-42496	Charcoal	A2	oven fill DW	7470	45	–23.79	56	6405–6340 (36.7%) 6315–6255 (31.5%)	SN08-479
GrA-42499	Charcoal	A2	oven fill DX	7445	45	–24.87	61	6380–6330 (28.8%) 6320–6250 (39.4%)	SN08-487
GrA-42500	Charcoal	A2	oven fill EF	7450	45	–23.10	62	6385–6330 (30.8%) 6320–6250 (37.4%)	SN08-495
GrA-42722	Charcoal	A2	room fill FZ with burnt material	7605	40	—	—	6475–6430 (68.2%)	SN08-300
GrA-42900	Charcoal	A2	open area	7475	50	–24.95	58	6415–6345 (39.9%) 6315–6220 (28.3%)	SN08-326b
GrA-32997	Charcoal	A1	room fill (*tho-los*), under floor AJ	7440	35	–21.35	62	6375–6330 (25.9%) 6320–6255 (42.3%)	SN05-298
GrA-33003	Charcoal	A1	room fill (*tho-los*) under pit EI and oven X	7425	35	–25.09	64	6365–6285 (51.2%) 6275–6245 (17.0%)	SN05-336
GrA-42334	Charcoal	A1	oven fill N	7420	45	–24.45	63	6365–6285 (48.2%) 6275–6240 (20.0%)	SN07-027
GrA-42337	Charcoal	A1	hearth fill KL	7445	45	–26.80	55	6380–6330 (28.8%) 6320–6250 (39.4%)	SN08-096
GrA-42338	Charcoal	A1	oven fill X in-side *tholos*	7380	45	–26.80	55	6365–6285 (34.9%) 6275–6215 (33.3%)	SN05-059
GrA-42340	Charcoal	A1	room fill	7400	45	–25.21	56	6365–6285 (42.1%) 6275–6225 (26.1%)	SN05-253

Appendix Date list of ^{14}C samples of charcoal and other charred materials for Tell Sabi Abyad. *(Continued)*

Lab code	Material	Level	Context	^{14}C BP	1 σ	$\delta^{13}C$ ‰	C_v %	cal BC (1 σ)	Sample ID
GrA-42342	Charcoal	A1	hearth fill EJ (*tholos*) under floor EE	7475	45	–24.38	56	6415–6345 (40.0%) 6315–6260 (28.2%)	SN05-331
GrA-42452	Charcoal	A1	hearth fill AU	7600	50	–23.39	57	6485–6415 (68.2%)	SN07-198
GrA-42453	Charcoal	A1	room fill	7440	45	–23.36	60	6380–6325 (28.1%) 6320–6250 (40.1%)	SN07-226
GrA-42455	Charcoal	A1	oven fill CW	7370	45	–24.04	61	6360–6110 (68.2%)	SN07-231
GrA-42456	Charcoal	A1	oven fill V	7445	45	–22.68	59	6380–6330 (28.8%) 6320–6250 (39.4%)	SN07-353
GrA-42457	Charcoal	A1	hearth fill AV	7480	45	–24.05	60	6420–6350 (42.0%) 6315–6260 (26.2%)	SN07-366
GrA-42459	Charcoal	A1	bin fill DA	7465	45	–22.74	62	6400–6340 (35.0%) 6315–6255 (33.2%)	SN07-463
GrA-42461	Charcoal	A1	bin fill CN	6930	45	–22.74	62	5870–5865 (2.1%) 5850–5740 (66.1%)	SN07-465
GrA-42462	Charcoal	A1	hearth fill inside *tholos*	7460	45	–23.36	62	6395–6335 (33.7%) 6315–6255 (34.5%)	SN07-607
GrA-42467	Charcoal	A1	oven fill HJ	7475	45	–24.59	65	6415–6345 (40.0%) 6315–6260 (28.2%)	SN08-304
GrA-42468	Charcoal	A1	hearth fill AU	7520	45	–25.04	57	6445–6365 (66.5%) 6280–6275 (1.7%)	SN08-364
GrA-42470	Charcoal	A1	hearth fill DO	7460	45	–23.75	61	6395–6335 (33.7%) 6315–6255 (34.5%)	SN08-391
GrA-42472	Charcoal	A1	oven fill DN	7165	45	–24.92	61	6065–6000 (68.2%)	SN08-393
GrA-42473	Charcoal	A1	hearth fill AV	7475	45	–24.01	60	6415–6345 (40.0%) 6315–6260 (28.2%)	SN08-485
GrA-42476	Charcoal	A1	room fill	7490	45	–24.58	62	6430–6265 (68.2%)	SN08-518
GrA-42477	Charcoal	A1	hearth fill DF	7415	45	–23.68	64	6365–6285 (46.3%) 6275–6235 (21.9%)	SN04-080
GrA-42479	Charcoal	A1	room fill	7455	45	–23.66	65	6395–6335 (32.3%) 6315–6255 (35.9%)	SN07-249
GrA-42866	Charcoal	A1	hearth fill CJ	7450	45	–22.86	60	6385–6330 (30.8%) 6320–6250 (37.4%)	SN07-356
GrN-28851	Charred grains	A1	room fill (upper level)	7400	25	—	—	6355–6310 (36.7%) 6265–6230 (31.5%)	SN03-010
GrN-28855	Charred grains	A1	room fill, on floor level?	7360	25	—	—	6330–6115 (68.2%)	SN03-077
GrA-42333	Charcoal	B8	oven fill R	7230	45	–23.70	64	6205–6025 (68.2%)	SN07-018
GrA-42336	Charcoal	B8	bin fill P	6880	40	–23.83	63	5805–5720 (68.2%)	SN07-046
GrA-42343	Charcoal	B8	bin fill AX	7230	45	–23.43	60	6205–6025 (68.2%)	SN07-101
GrA-42344	Charcoal	B8	vessel fill BM	7230	45	–23.31	59	6205–6025 (68.2%)	SN07-104
GrA-42346	Charcoal	B8	bin fill AX	7250	45	–23.87	60	6210–6135 (38.1%) 6110–6060 (30.1%)	SN07-109
GrA-42347	Charcoal	B8	oven fill BK	7360	45	–22.96	59	6350–6100 (68.2%)	SN07-110
GrA-42486	Charcoal	B8	vessel (P07-048) fill in Burial 32	7250	45	–23.51	60	6210–6135 (38.1%) 6110–6060 (30.1%)	SN07-195
GrA-42862	Charcoal	B8	oven fill BB	7360	45	–24.06	57	6350–6100 (68.2%)	SN07-230
GrA-42864	Charcoal	B8	oven fill BM	7365	45	–23.25	58	6355–6105 (68.2%)	SN07-275
GrA-42865	Charcoal	B8	hearth fill BE	7315	45	–13.33	42	6230–6200 (16.3%) 6195–6100 (51.9%)	SN07-278
GrA-42868	Charcoal	B8	oven fill BP	7320	45	–24.63	59	6230–6200 (17.2%) 6195–6100 (51.0%)	SN07-473
GrA-42890	Charcoal	B8	oven fill BZ	7305	40	–26.64	63	6225–6200 (13.3%) 6195–6100 (54.9%)	SN07-518

Appendix Date list of ^{14}C samples of charcoal and other charred materials for Tell Sabi Abyad. *(Continued)*

Lab code	Material	Level	Context	^{14}C BP	1 σ	$\delta^{13}C$ ‰	C_v %	cal BC (1 σ)	Sample ID
GrA-42891	Charcoal	B8	oven fill CC	7280	45	–22.64	58	6215–6135 (49.0%) 6115–6080 (19.2%)	SN07-569
GrA-42893	Charcoal	B8	hearth fill FI	7355	45	–25.91	57	6340–6100 (68.2%)	SN08-198
GrA-42894	Charcoal	B8	oven fill FZ	7350	45	–22.04	50	6330–6095 (68.2%)	SN08-471
GrA-42855	Charcoal	B7	pit fill BC	7245	45	–23.57	56	6210–6135 (35.8%) 6110–6055 (32.4%)	SN07-081
GrA-42856	Charcoal	B7	pit fill BE	7375	45	–23.59	61	6365–6120 (68.2%)	SN07-083
GrA-42858	Charcoal	B7	pit fill GG	7290	45	–23.35	58	6215–6095 (68.2%)	SN08-467
GrA-42859	Charcoal	B7	oven fill GB	7325	45	–23.13	58	6235–6200 (19.2%) 6195–6100 (49.0%)	SN08-470
GrA-42860	Charcoal	B7	oven fill GC	7215	45	–22.61	58	6205–6015 (68.2%)	SN08-472
GrA-42869	Charcoal	B7	oven fill CB	7225	45	–24.12	61	6205–6020 (68.2%)	SN07-515
GrA-42846	Charcoal	B6	hearth fill CO	7360	45	–23.51	59	6350–6100 (68.2%)	SN07-180
GrA-42848	Charcoal	B6	hearth fill CE	7285	45	–23.24	58	6215–6130 (50.6%) 6125–6090 (17.6%)	SN07-183
GrA-42849	Charcoal	B6	oven fill BF	7250	45	–24.29	59	6210–6135 (38.1%) 6110–6060 (30.1%)	SN07-371
GrA-42853	Charcoal	B6	hearth fill	7240	50	–23.21	56	6210–6135 (33.9%) 6110–6050 (34.3%)	SN08-060
GrA-42854	Charcoal	B6	bin fill surrounded by ET/EU/EY	7200	45	–21.93	52	6095–6005 (68.2%)	SN08-158
GrA-42839	Charcoal	B5	oven fill CC	7140	45	–23.35	59	6055–5985 (68.2%)	SN07-347
GrA-42840	Charcoal	B5	oven fill BW	7180	50	–24.36	63	6080–5995 (68.2%)	SN07-349
GrA-42843	Charcoal	B5	oven fill BN	7195	45	–23.37	56	6090–6005 (68.2%)	SN07-355
GrA-42844	Charcoal	B5	oven fill BH	7090	45	–23.05	58	6020–5970 (38.3%) 5955–5915 (29.9%)	SN07-370
GrA-42845	Charcoal	B5	oven fill CF	7240	45	–22.36	60	6210–6140 (32.6%) 6110–6050 (35.6%)	SN07-514
GrA-42887	Charcoal	B5	hearth fill DO	7235	40	–25.37	60	6210–6030 (68.2%)	SN07-567
GrA-42833	Charcoal	B4	oven fill L	7315	40	–23.52	58	6230–6200 (16.6%) 6195–6100 (51.7%)	SN07-070
GrA-42834	Charcoal	B4	oven fill M	7135	40	–23.62	56	6050–5985 (68.2%)	SN07-074
GrA-42835	Charcoal	B4	oven fill AV	7160	40	–23.51	57	6060–6000 (68.2%)	SN07-129
GrA-42836	Charcoal	B4	oven fill AN	6045	40	–22.69	56	5005–4895 (61.6%) 4870–4850 (6.6%)	SN07-148
GrA-42838	Charcoal	B4	silo/oven fill AR	7020	45	–23.48	56	5985–5845 (68.2%)	SN07-160
GrA-42822	Charcoal	B3	hearth fill AJ	7200	45	–23.99	57	6095–6005 (68.2%)	SN07-094
GrA-42824	Wood	B3	room fill	6530	40	–23.96	54	5535–5470 (68.2%)	SN07-163
GrA-42825	Charcoal	B3	room fill	7130	45	–23.69	53	6050–5985 (68.2%)	SN07-194
GrA-41269	Charcoal	—	sample from Oven T	9730	50	–12.24	3	9275–9180 (68.2%)	SN08-042
GrA-41271	Charcoal + roots	—	oven fill U	5140	40	–21.87	23	3990–3940 (45.4%) 3860–3815 (22.8%)	SN08-113
GrA-43008	Charcoal + roots	—	oven fill AK	7010	45	–24.89	27	5980–5945 (21.1%) 5925–5845 (47.1%)	SN08-365
GrA-32993	Charcoal	—	Burial 03 (LN): grave fill AG	7200	35	–26.34	63	6080–6015 (68.2%)	SN05-203
GrA-32996	Charcoal	—	Burial 03 (LN): grave fill AG	7460	80	–22.70	61	6405–6245 (68.2%)	SN05-273